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EXQ60 Dual

Application Note 117

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ARTESYN® TECHNOLOGIES

Rev. 03 / 22 October 2002

- **Two positive outputs**
- **Output voltage tracking**
- **High efficiency topology**
- **Approved to EN60950 (TÜV Rheinland), UL/cUL1950**
- **Wide baseplate operating temperature range, -40°C to +100°C**
- **Up to 100% load imbalance**
- **Trim function**
- **No minimum load**
- **Complies with ETS 300 019-1-3/2-3**
- **Fully compliant with ETS 300 386-1**

1. Introduction

This application note describes the features and functions of Artesyn Technologies' EXQ60 series of high power density, quarter-brick DC/DC converters. These open-frame, dual-output modules are targeted specifically at the fixed and mobile telecommunications, industrial electronics and distributed power markets.

All EXQ60 series converters offer a wide input voltage range of 33-75VDC and feature a wide baseplate operating temperature range of -40°C to +100°C. Ultra-high efficiency operation is achieved through the use of proprietary synchronous rectification and control techniques. The modules have a ±10% output voltage trim range, and are fully protected against over-current, over-voltage and over-temperature conditions. A remote on/off facility is provided as standard.

The EXQ60 series is designed primarily for telecommunication applications and complies with ETS 300 386-1 immunity and emission standards for high priority of service class. In addition, the series complies with ETS 300 019-1-3/-2-3 environmental standards (all classes) including shock, vibration, humidity and thermal performance. EN60950 and UL/cUL1950 safety approvals have been obtained, and a high level of reliability has been designed into all models through extensive use of conservative de-rating criteria. Automated manufacturing methods, together with an extensive qualification program, ensure that all EXQ60 series converters are produced to the same rigorous quality levels.

2. Models

The EXQ60 series comprises two models, as listed in Table 1.

Model	Input Voltage	Output Voltage	Output Current
EXQ60-48D05-3V3	33-75VDC	5.0V/3.3V	12A/15A
EXQ60-48D3V3-2V5	33-75VDC	3.3V/2.5V	12A/16A

Table 1 - EXQ60 Models

Features

- Industry standard dual-output quarter-brick pinout and footprint: 58.4 x 38.1 x 12.7mm (2.3 x 1.5 x 0.5 inches)
- Wide operating temperature range (-40°C to +100°C baseplate temperature)
- ±10% output voltage adjustability
- No minimum load requirement
- Remote on/off control (primary-side referenced)
- Constant switching frequency
- Brickwall over-current protection
- Continuous short-circuit protection
- Non-latching output over-voltage protection (OVP)
- Over-temperature protection (OTP)
- Input under/over-voltage lockout protection (U/OVLO)

3. General Description

3.1 Electrical Description

A block diagram of the EXQ60 converter is shown in Figure 1. Extremely high efficiency power conversion is achieved through the use of synchronous rectification techniques (patents pending).

The EXQ60 is implemented using a current-mode controlled interleaved flyback topology. Power is transferred magnetically across the isolation barrier via isolating power transformers. In all models, the secondary-side rectification stage consists of synchronous rectifiers controlled by proprietary circuitry to optimize the timing, which is critical for high efficiency power conversion. Two tightly coupled cross-regulated output voltages are provided. Each output is adjustable over a range of 90% to 110% of its nominal value, using the TRIM pin which is referenced to V_{out-}.

The converter can be shut down via a remote on/off input that is referenced to the primary side. The input is compatible with popular logic devices; a 'positive' logic input is provided as standard, with 'negative' logic available as an option. Positive logic implies that the converter is enabled if the remote on/off input is high (or floating) and disabled if it is low. Conversely, negative logic implies that the converter is enabled if the remote on/off input is low, and disabled if it is high (or floating).

The cross-coupled outputs are monitored for over-voltage conditions. The converter will clamp at the over-voltage set-point if an over-voltage condition caused by an internal fault is detected at either output.

The converter is also protected against over-temperature conditions. If the converter is overloaded or the baseplate temperature gets too high, the converter will shut down until the temperature falls below a minimum threshold. There is a thermal hysteris of typically 3 to 5ºC, to protect the unit.

An internal second-order input filter (LC) smoothes the input current and reduces conducted and radiated EMI. Further improvement can be achieved through the use of an optional external input filter. See section 6.1 for further details.

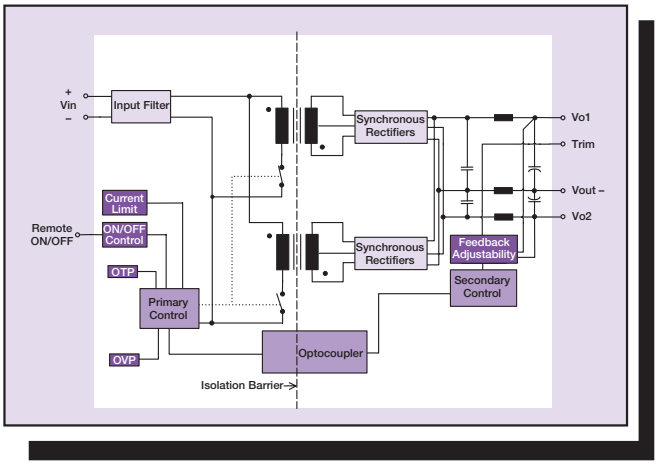


Figure 1 - Electrical Block Diagram

3.2 Physical Construction

The EXQ60 is constructed using a multi-layer FR4 PCB and an insulated metal substrate (IMS). SMT power components are placed on one side of the IMS while low power control components are placed on both sides of the PCB. This approach optimizes heat dissipation of the power components mounted on the baseplate, and also thermally isolates the critical control components.

The converter is an open-frame product and has no case or case pin. The open-frame design has several advantages over encapsulated closed devices, including:

- **Cost:** no potting compound, case or associated process costs involved
- **Thermals:** the heat is removed from the heat generating components without heating more sensitive, less tolerant components such as opto-couplers
- **Environmental:** some encapsulants are not kind to the environment and create problems in incinerators. Furthermore, open-frame converters are more easily re-cycled
- **Reliability:** open-frame modules are more reliable for a number of reasons, including improved thermal performance and reduced thermal coefficient of expansion (TCE) stresses

A separate paper discussing the benefits of open-frame DC/DC converters (Design Note 102) is available at www.artesyn.com.

4. Features and Functions

4.1 Wide Operating Temperature Range

The EXQ60's ability to accommodate a wide range of ambient temperatures is the result of its extremely high power conversion efficiency and resultant low power dissipation, combined with the excellent thermal performance of its IMS. The maximum output power that the module can deliver depends on a number of parameters, primarily:

- Input voltage range of target application
- Output load current of target application
- Air velocity (if used in a forced convection environment)
- Mounting orientation of target application PCB, i.e. vertical/horizontal mount, or mechanically tied down (especially important in natural convection conditions)
- Target application PCB design, especially with respect to ground planes, which can provide effective heatsinks for the converter

The converter can be operated from -40ºC to a maximum baseplate temperature of +100ºC. A number of design graphs are included in the long-form datasheet that simplify the design task and allow the power system designer to determine the maximum output current at which the EXQ60 module may be operated for a given baseplate temperature and airflow.

4.2 Over-Temperature Protection

All EXQ60 converters feature non-latching over-temperature protection. The temperature of the main substrate is monitored by a sensor. If the temperature exceeds a threshold of 113°C (typical) the converter will shut down, disabling the output. When the substrate temperature has decreased by between 3°C and 5°C, the converter will automatically restart.

The converter might experience over-temperature conditions during a persistent overload on its output. Overload conditions can be caused by external faults. OTP might also be entered due to a loss of control of the environmental conditions (e.g. an increase in the converter's temperature due to a failing fan).

4.3 Output Voltage Adjustment

The output voltage on all models is trimmable by -10% to +10% of the nominal output voltage. Details on how to trim all models are provided in section 8.5.

4.4 Output Over-Voltage Protection

The clamped over-voltage protection (OVP) feature is used to protect the module and the user's circuitry in the unlikely event of a fault occurring in the main control loop. Faults of this type include optocoupler failure, an open-circuit sense resistor or error amplifier failure.

The OVP circuit consists of an auxiliary control loop running in parallel to the main control loop. However, unlike the main loop, the OVP loop senses the cross-coupled output voltages on the primary side of the converter. This voltage is compared to a separate OVP reference and a compensated error signal is generated such that the output voltage is regulated to the OVP clamp level. Note that an optocoupler is not required during operation of the OVP clamp circuit. OVP clamp levels are typically set at 120-125% of the nominal output voltage set-point for all models.

4.5 Safe Operating Area

The Safe Operating Area (SOA) of the EXQ60 converter is shown in Figure 2. Assuming the converter is operated within its thermal hotspot constraints, it can deliver an output current $I_{o,max}$ as shown in Figure 2. Note, however, that the SOA does not remain valid across the full trim range of the converter. For example, if the unit is trimmed up by 10%, the output current must be correspondingly derated by 10%. The module can still deliver $I_{o,max}$ when trimmed down.

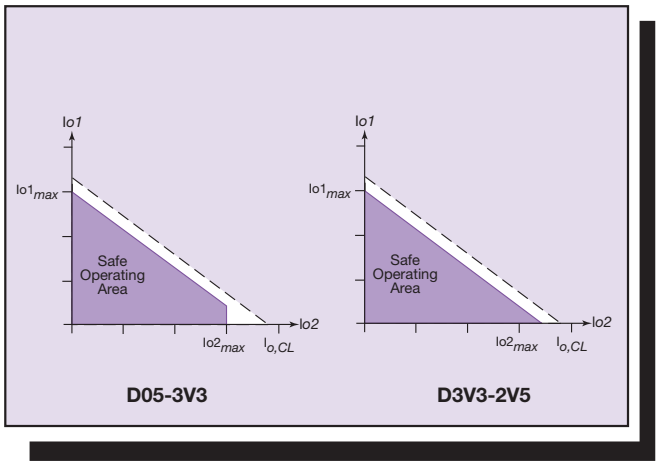


Figure 2 - Maximum Output Current Safe Operating Area

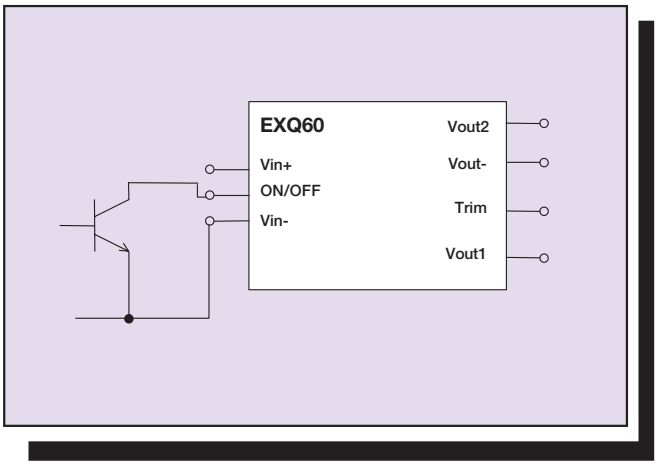


Figure 3 - Remote ON/OFF Input Drive Circuits for Non-Isolated Bipolar

It should be noted that the SOA shown in Figure 2 is valid only if the converter is operated within its thermal specification. See section 8.2 for further details.

4.6 Brickwall Current Limit and Short-Circuit Protection

All EXQ60 models have a built in brickwall current limit function and full continuous short-circuit protection. Thus the V–I characteristic in current limit will be almost vertical at the current limit inception point, $I_{o,CL}$. This means that the output current should be almost constant, irrespective of the output voltage during overload. The current limit inception point is dependent upon baseplate temperature, line voltage and, for a given output, the load split. For all models, the inception point is typically 115% of rated full power. The brickwall current limit scheme has many advantages, including increased capacitive load start-up capability (see section 8.7).

Note that although none of the module specifications is guaranteed when the unit is operated in an over-current condition, the unit will not be damaged, because it will be protected by the OTP function.

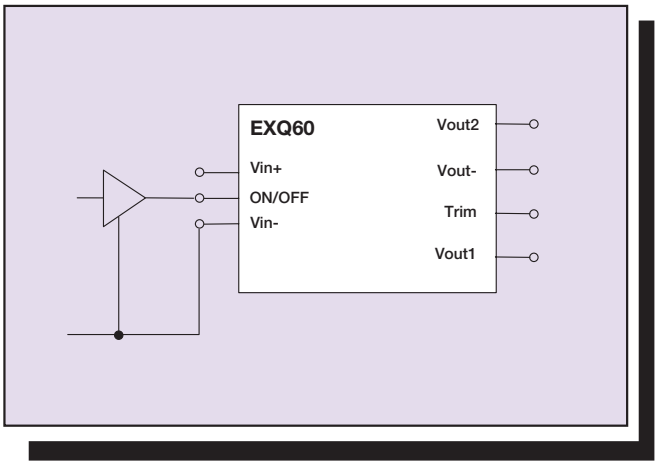


Figure 4 - Remote ON/OFF Input Drive Circuits for Logic Driver

4.7 Remote ON/OFF

The remote ON/OFF input allows external circuitry to put the EXQ60 converter into a low dissipation sleep mode. Active-high remote ON/OFF is available as standard and active-low logic can be specified by adding the suffix '-R' to the part number.

Active-high units of the EXQ60 series are turned on if the remote on/off pin is high (or left floating). Pulling the pin low will turn the unit off. Active-low units are turned on if the remote ON/OFF pin is low. Pulling the pin high (or leaving it floating) will turn the unit off. The signal level of the remote on/off input is defined with respect to V_{in-}.

To simplify the design of the external control circuit, logic signal thresholds are specified over the full temperature range. The maximum remote ON/OFF input open-circuit voltage, as well as the acceptable leakage currents, are specified in the EXQ60 long-form datasheet. These specifications apply to both the standard and active-low logic versions.

The remote ON/OFF input can be driven in a variety of ways as shown in Figures 3, 4 and 5. If the remote ON/OFF signal originates on the primary side, the remote ON/OFF input can be driven through a discrete device (e.g. a bipolar signal transistor), or directly from a logic gate output. The output of the logic gate can be an open-collector (or open-drain) device. If the drive signal originates on the secondary side, the remote on/off input can be isolated and driven through an optocoupler.

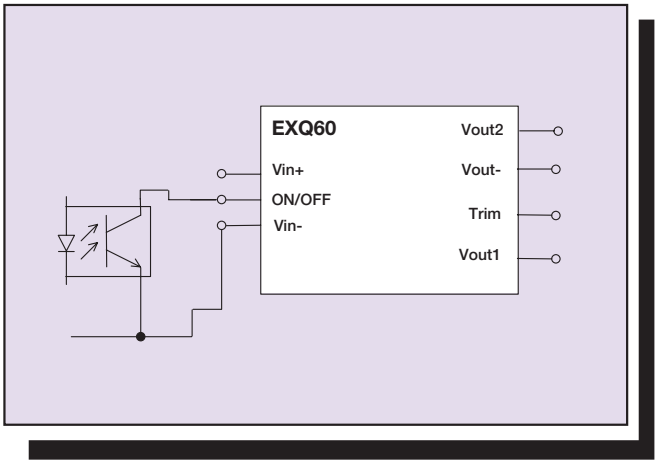


Figure 5 - Remote ON/OFF Input Drive Circuits for Isolation through Optocoupler

5. Safety

5.1 Electrical Isolation

The EXQ60 has been submitted to independent safety agencies and has EN60950 and UL1950 safety approvals. Operational insulation is provided between the input and output of the DC/DC power module in accordance with EN60950. The module should be installed in end-use equipment in compliance with the requirements of the application and is intended to be supplied by an isolated secondary circuit. It has been judged on the basis of the required spacings in the Standard of Safety and Information Technology Equipment, including electrical business equipment, CAN/CSA-C22.2, No. 950-95 UL1950, third edition, including revisions through revision date March 1, 1998, which are based on the fourth amendment to EN60950, second edition, sub-clause 2.9 for use in the United States and Canada.

When the supply to the DC/DC power module meets all the requirements for SELV (<60VDC), the output is considered to remain within SELV limits and not at hazardous energy levels. If connected to a 60V DC power system, reinforced insulation must be provided in the power supply that isolates the input from the mains.

The galvanic isolation is verified in an electric strength test in production; the test voltage between input and output is 1.5kVDC. Also, note that flammability ratings of the terminal support header blocks and internal plastic constructions meet UL94V-0.

5.2 Input Fusing

The EXQ60 power module can be used in a wide variety of applications, ranging from simple stand-alone operation to an integrated part of a sophisticated distributed power architecture. To preserve maximum flexibility, internal fusing is not included. However, in order to comply with safety requirements, the user must provide a fuse in the unearthed input line if an earthed input is used. The reason for putting the fuse in the unearthed line is to avoid earth being disconnected in the event of a failure. If an earthed input is not being used, the fuse can be placed in either input line. The recommended fuse rating for the EXQ60 converter is 5A, HRC (high rupture capacity), anti-surge, rated for 200V. A fuse should be used at the input of each EXQ60 module. If a fault occurs in the module such that the input source is shorted, the fuse will provide the following two functions:

- Isolate the failed module from the input source, in order that the remainder of the system can continue operating
- Protect the distribution wiring from overheating

Based on the information provided in the long-form data sheet on inrush energy and maximum DC input current, the same type of fuse with a lower rating can be used, depending on model. Refer to the fuse manufacturer's data for further information.

6. EMC

The EXQ60 is designed to comply with the EMC requirements of ETSI 300 386-1. It meets the most stringent requirements of Table 5; 'public telecommunications equipment, locations other than telecommunication centres, high priority of service'. The following sections detail the list of standards which apply and with which the product complies.

6.1 Conducted Emissions

The applicable standard for conducted emissions is EN55022 (FCC Part 15). Conducted noise can appear as both differential-mode and common-mode noise currents. Differential-mode noise is measured between the two input lines, with the major components occurring at the converter's fundamental switching frequency and its harmonics. Common-mode noise, generated in switching converters, can contribute to both radiated emissions and input conducted emissions; it is measured between the input lines and system ground, and can be broadband in nature. The EXQ60 series of converters bypasses common-mode noise internally by using two paralleled 1nF, 2kV capacitors between V_{in} and V_o. Common-mode noise currents flowing in the application circuitry will therefore be minimized. Furthermore, the EXQ60 has a substantial second-order differential-mode filter on board, to enable it to meet the above standard using a simple externally connected differential- and common-mode filter. The circuit diagram of the filter required for Class B compliance is presented in Figure 6.

Differential-mode noise is attenuated by a π-filter comprised of the series inductance presented by the leakage inductance of the common mode choke, L_{x1}, and the X-capacitors, C_{x1} and C_{x2}. The converter-side capacitor is typically an electrolytic with a relatively significant ESR component that helps maintain input system stability.

The common-mode noise filter comprises the Y-capacitors, C_{y1} and C_{y2}, from each input line to a chassis ground plane, capacitors C_{y3} and C_{y4} from each output line to the ground plane, and the common-mode choke, L_{x1}. The ground plane can be connected to the case when case tie-downs are employed. Resistors R_{y1} and R_{y2} help damp any high frequency oscillation occurring around the common mode loop.

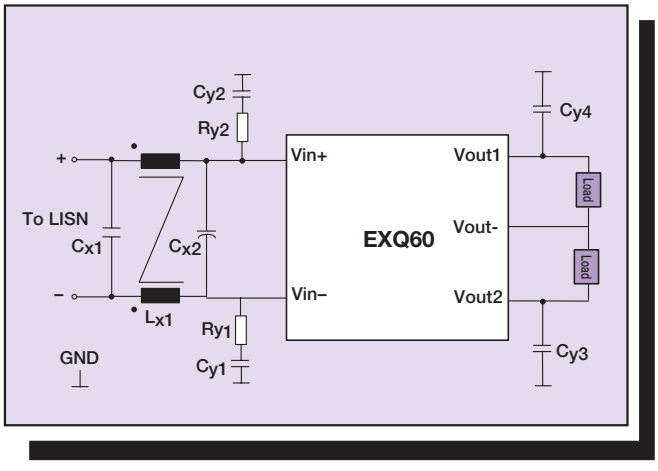


Figure 6 - Recommended Class B Filter

The components used in the filter shown in Figure 6, together with the manufacturers' part numbers for these components, are as follows:

C_{x1}: ITW Paktron 4µF, 100V, SMT film capacitor, 405K100CS4
C_{x2}: UCC 33µF, 100V, electrolytic capacitor, KMF100VB33RM10X12
C_{y1}, C_{y2}: 2 x AVX 5.6nF, 1.5kV, 1812SC562KA1
C_{y3}, C_{y4}: 2 x AVX 0.1µF, 100V, 12061C104KAT
R_{y1}, R_{y1}: 2 x 5.6Ω 1206 resistor
L_{x1}: Pulse Eng PO351

General recommended layout guidelines of the specified filter are shown in Figure 7. Section 8.1 discusses this subject in more detail.

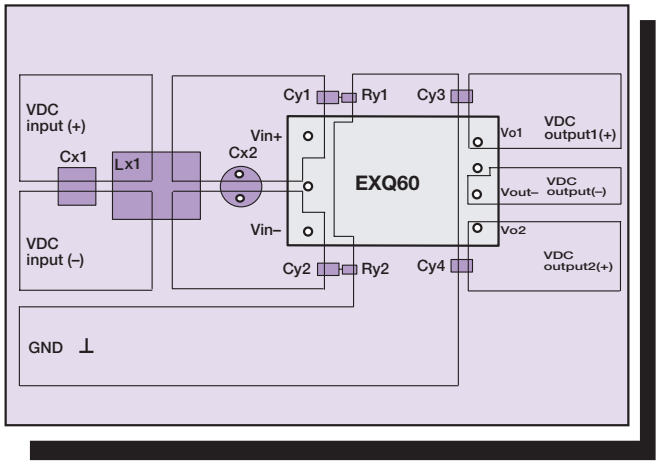


Figure 7 - Conducted EMI Filter Recommended Layout Guidelines

Typical conducted emission measurement results are shown in Figure 8. The results were obtained using the recommended external Class B input filter as outlined in Figure 6.

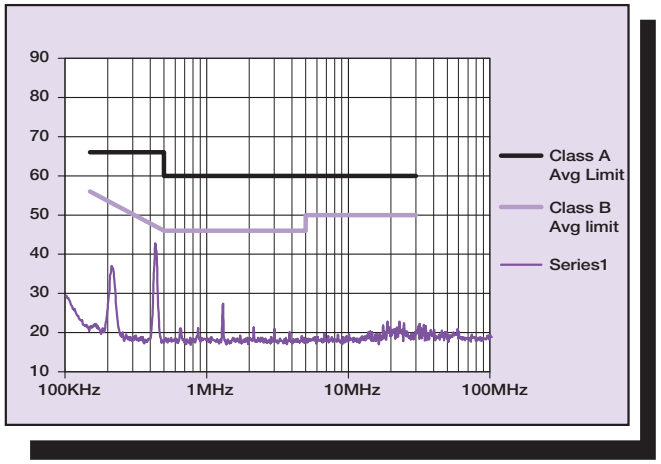


Figure 8 - Typical Spectrum of the EXQ60-48D05-3V3 (Vin=48V, Io1=6A, Io2=9A), 50µH LISN, Class A and B Average Limit Lines are Shown

6.2 Radiated Emissions

The applicable standard is EN55022 Class B (FCC Part15). Testing DC/DC converters as a stand-alone component to the exact requirements of EN55022 is very difficult to do, because the standard calls for 1 meter leads to be attached to the input and output ports and aligned such as to maximize the disturbance. In such a set-up it is possible to form a perfect dipole antenna that very few DC/DC converters could pass.

However the standard also states that 'an attempt should be made to maximize the disturbance consistent with the application by varying the configuration of the test samples'. In addition, ETS 30 381-1 states that the testing should be carried out on the enclosure. The EXQ60 is primarily intended for PCB mounting in telecommunication rack systems. Signal input lines to the converter are considered to be less than 3 meters in length to meet the standards.

For the purpose of the radiated test on EXQ60-48D05-3V3 was mounted on a 227.3mm x 127mm (8.95in x 5.0in) test-board using recommended PCB layout (See Appendix 1) and no enclosure was used. The operating conditions were:

- Input voltage, V_{in} = 48V
- Output1 current I_o1 = 7.0A
- Output2 current, I_o2 = 2.0A

The test results showed that the EXQ60-48D05-3V3 was well within the Class B radiated emission requirements of EN55022 and the only detectible responses are shown below.

Frequency (Megahertz)	Response (dBµ V/M)	Limit (dBµ V/M)
49.50	11.10	30.00
154.20	16.35	30.00

7. Use in a Manufacturing Environment

7.1 Resistance to Soldering Heat

All EXQ60 series converters are intended for PCB mounting. Artesyn Technologies has determined how well the product can resist the temperatures associated with the soldering of PTH components without affecting its performance or reliability. The method used to verify this is MIL-STD-202 method 210D. Within this method, two test conditions were specified: Soldering Iron condition A and Wave Solder condition C.

For the soldering iron test, the UUT was placed on a PCB with the recommended PCB layout pattern shown in section 8. A soldering iron set to 350°C±10°C was applied to each terminal for 5 seconds. The UUT was then removed from the test PCB and examined under a microscope for any reflow of the pin solder or physical change to the terminations. None was found.

For the wave solder test, the UUT was again mounted on a test PCB. The unit was wave soldered using the conditions shown in Table 2. The UUT was inspected after soldering and no physical change was found on the pin terminations.

Temperature	Time	Temperature Ramp
260°C±5°C	10sec±1	Preheat 4°C/sec to 160°C, 25mm/sec rate

Table 2 -Wave Solder Test Conditions

7.2 Water Washing

The EXQ60 is suitable for water washing, because it does not have any pockets where water could be trapped long-term. Users should ensure that the drying process is adequate and of sufficient duration to remove all water from the converter after washing – do not power-up the unit until it is completely dry.

7.3 ESD Control

The EXQ60 units are manufactured in an ESD controlled environment and supplied in conductive packaging to prevent ESD damage occurring before or during shipping. It is essential that they are unpacked and handled using approved ESD control procedures. Failure to do so could affect the lifetime of the converter.

8. Applications

8.1 Optimum PCB Layout

The PCB acts as a heatsink and draws heat from the unit via conduction through the pins and radiation. It is recommended that power and return planes be used. A three-wire system including a chassis or system ground is also possible, and a ground plane here is also beneficial. These planes act as EMC shields (note that the recommended layout shown in Figure 7 does not guarantee system EMC compliance, since this depends on the end application). A recommended PCB layout is presented in Appendix 1. Low resistance and low inductance PCB layout traces should be used where possible, particularly where high currents are flowing (such as on the output side).

8.2 Optimum Thermal Performance

The maximum acceptable baseplate temperature for EXQ60 series converters is +100°C, as measured at the thermal reference point shown in Figure 9.

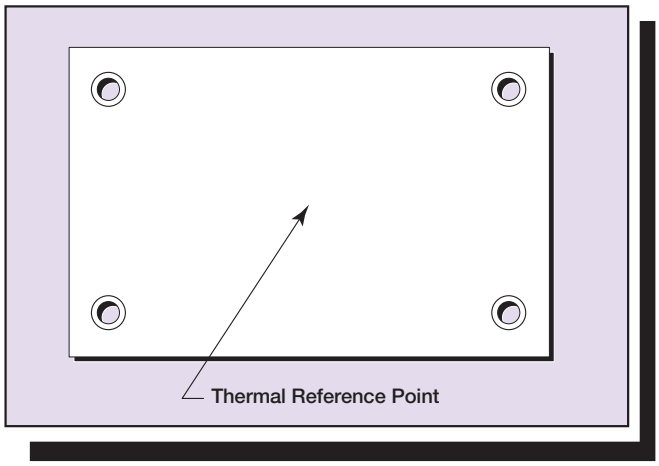


Figure 9 - EXQ60 Baseplate Temperature Check Point

The temperature of the baseplate is directly influenced by the amount of power being dissipated within the converter, and by the environmental conditions in which it is operating. The dissipated power is determined by the converter's electrical operating conditions, in terms of:

- Input voltage, V_{in}
- Output voltage, V_{o1} and V_{o2}
- Output current, I_{o1} and I_{o2}

And the environmental operating conditions that affect baseplate temperature are:

- Ambient temperature
- Air velocity
- Thermal efficiency of the end system application

To simplify the thermal design task a number of graphs are given in the long-form data sheet and are repeated here in Figures 10 through to 16 inclusive. The de-rating graphs show the output power of the EXQ60-48D05-3V3 converter with the mechanical tie-downs screwed onto a ground plane, and the output power of the EXQ60-48D3V3-2V5 without the use of mechanical tie-downs (no de-rating was required in airflow with the mechanical tie-downs screwed onto the ground plane of the test board) for various load splits, versus the ambient air temperature and forced air velocity. However, since the thermal performance is heavily dependent upon the final system application, the user needs to ensure that the baseplate is kept within its recommended temperature rating. It is recommended that the temperature of the baseplate is measured using a thermocouple or an IR camera. In order to comply with Artesyn's stringent de-rating criteria, the baseplate temperature should not exceed +100°C.

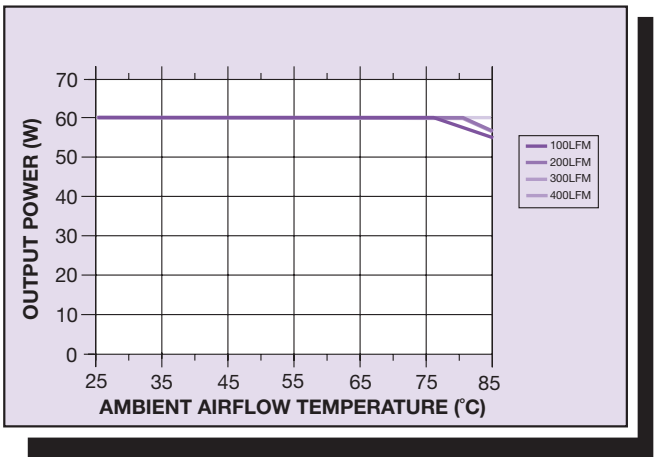


Figure 10 - Maximum Output Power vs. Ambient Temperature and Airflow for EXQ60-48D05-3V3 Model, 100% Load from V_{out1}

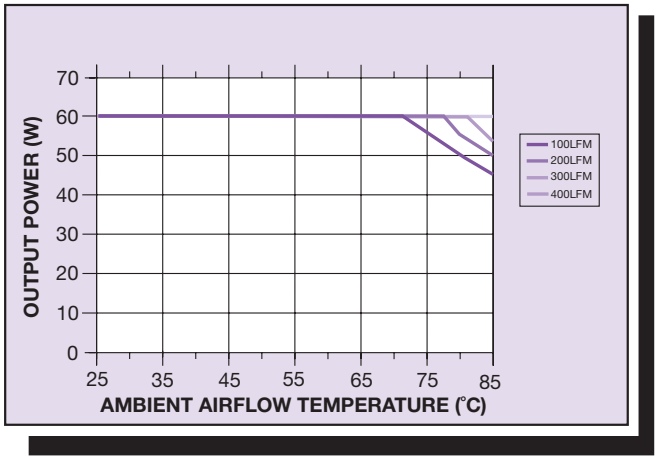


Figure 11 - Maximum Output Current vs. Ambient Temperature and Airflow for EXQ60-48D05-3V3 Model, 100% Load from V_{out2}

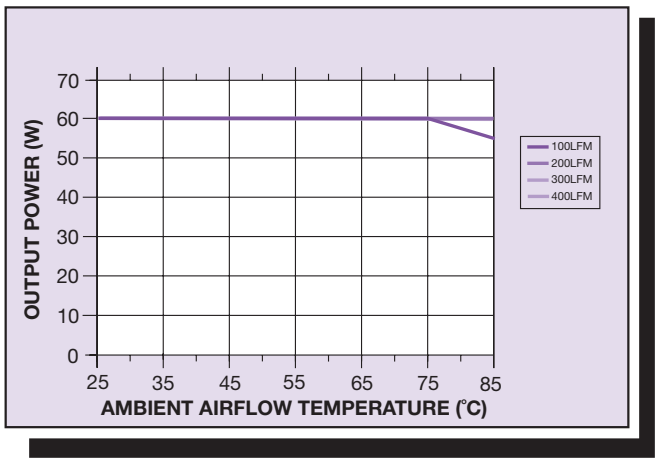


Figure 12 - Maximum Output Current vs. Ambient Temperature and Airflow for EXQ60-48D05-3V3 Model, 50% Load Split

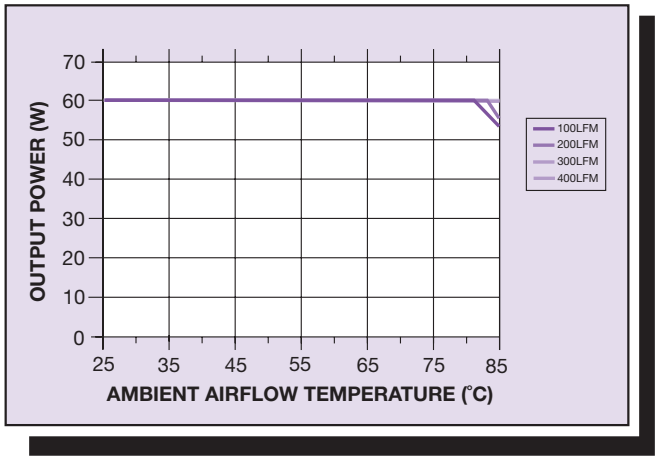


Figure 13 - Maximum Output Current vs. Ambient Temperature and Airflow for EXQ60-48D05-3V3 Model, 30% Load from V_{out1}, 70% Load from V_{out2}

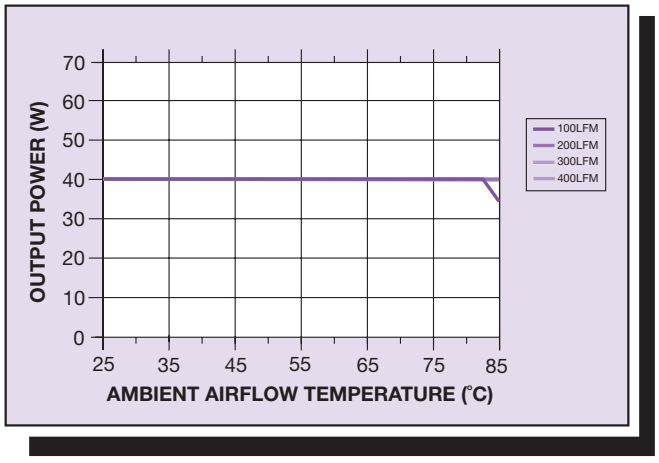


Figure 14 - Maximum Output Current vs. Ambient Temperature and Airflow for EXQ60-48D3V3-2V5 Model, 100% Load from V_{out1}

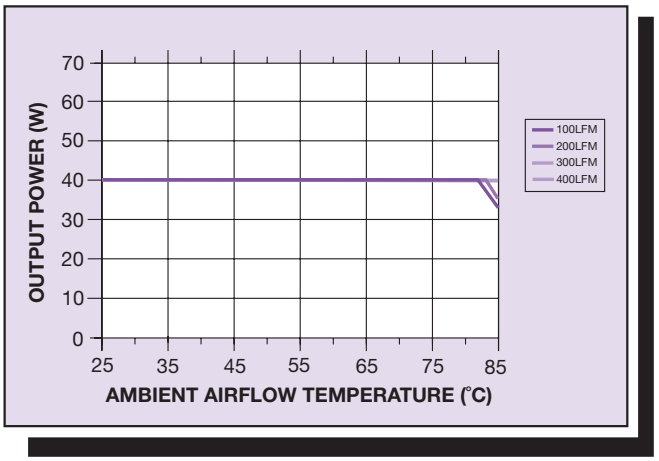


Figure 15 - Maximum Output Current vs. Ambient Temperature and Airflow for EXQ60-48D3V3-2V5 Model, 100% Load from V_{out2}

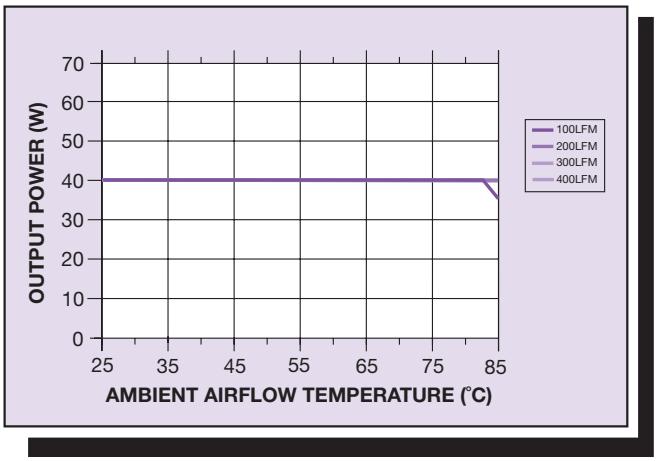


Figure 16 - Maximum Output Current vs. Ambient Temperature and Airflow for EXQ60-48D3V3-2V5 Model, 70% Load from V_{out1}, 30% Load from V_{out2}

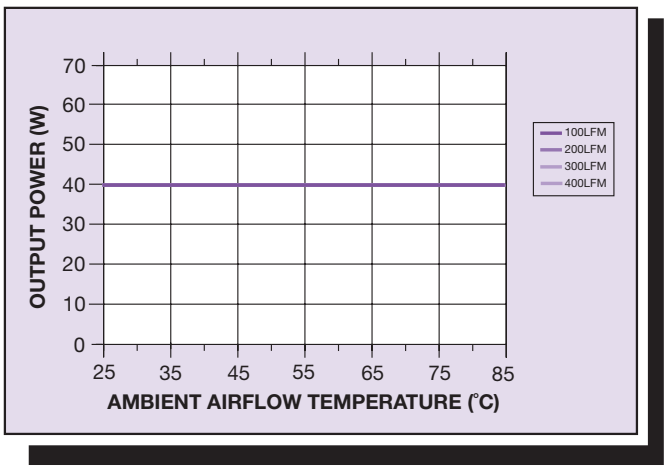


Figure 17 - Maximum Output Current vs. Ambient Temperature and Airflow for EXQ60-48D05-3V3-2V5 Model, 50% Load Split

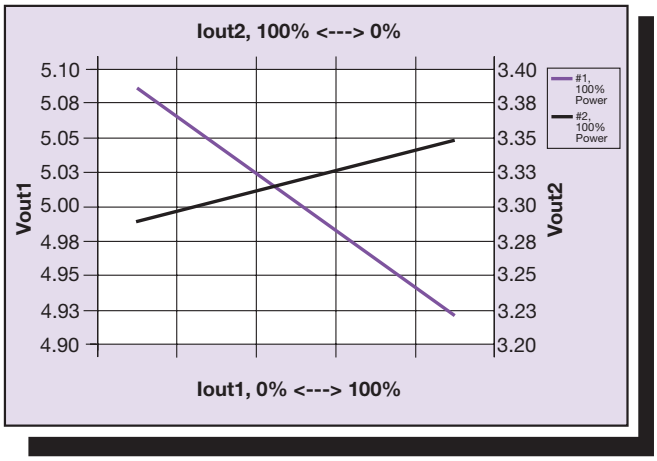


Figure 18 - EXQ60-48D05-3V3 Typical Cross Regulation at P_{out} = 100% P_{outmax}

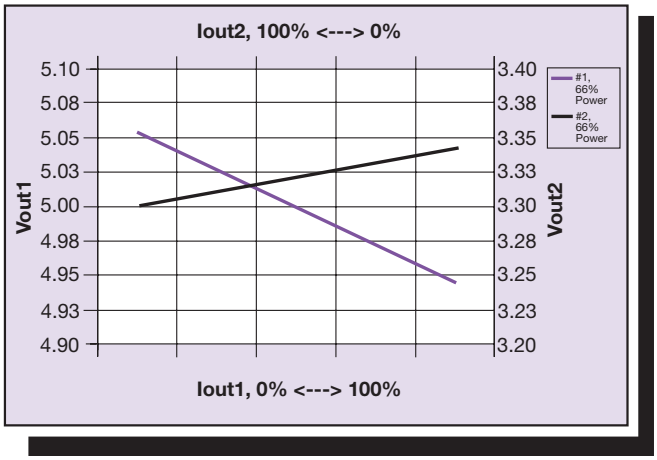


Figure 19- EXQ60-48D05-3V3 Typical Cross Regulation at P_{out} = 66% P_{outmax}

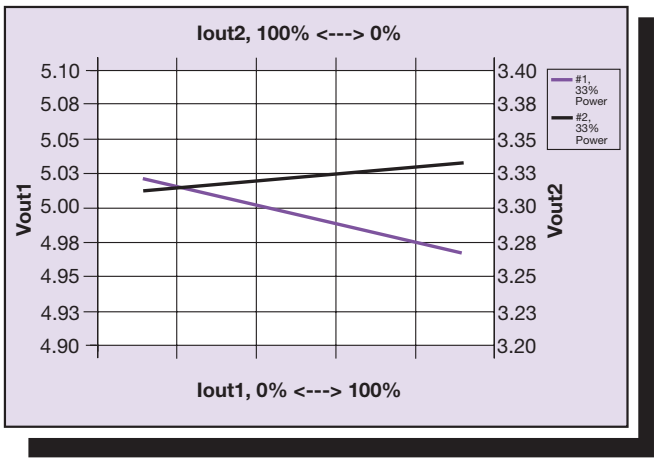


Figure 20 - EXQ60-48D05-3V3 Typical Cross Regulation at P_{out} = 33% P_{outmax}

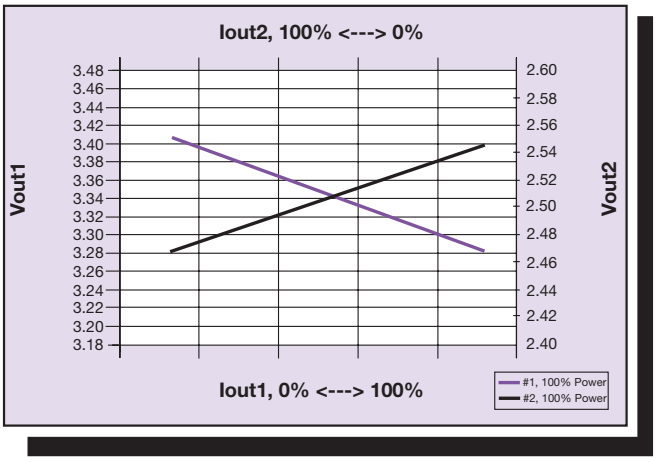


Figure 21 - EXQ60-48D3V3-2V5 Typical Cross Regulation at P_{out} = 100% P_{outmax}

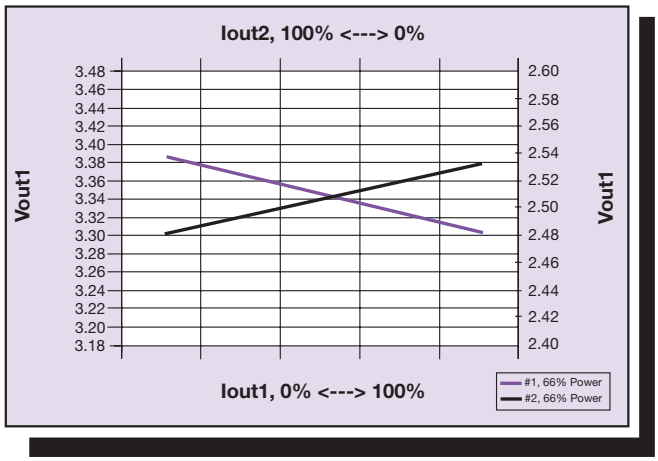


Figure 22 - EXQ60-48D3V3-2V5 Typical Cross Regulation at P_{out} = 66% P_{outmax}

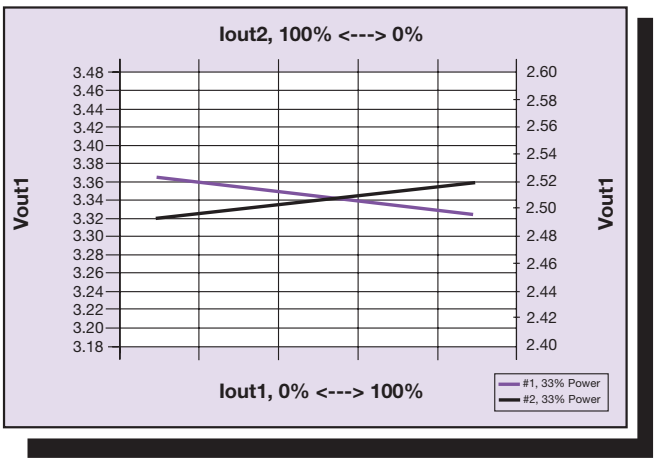


Figure 23 - EXQ60-48D3V3-2V5 Typical Cross Regulation at P_{out} = 33% P_{outmax}

8.3 Remote Sense Compensation

The EXQ60 features a multi-output, shared regulation scheme working on tightly coupled cross-regulated outputs. Remote sense compensation is not applicable to this type of system.

8.4 Output Cross-Regulation

Typical output voltage cross-regulation against load split curves are given for 100%, 66% and 33% output loading conditions in Figures 17 through to 22 inclusive.

8.5 Output Voltage Adjustment

The output can be externally trimmed by ±10% by connecting an external resistor between the TRIM pin and either the V_{out2} or V_{out-} pin. With an external resistor between TRIM and V_{out2}, R_{TRIM_DOWN}, the output voltage set-point decreases. Conversely, connecting an external resistor between TRIM and V_{out-}, R_{TRIM_UP}, will increase the output voltage set-point. A trim potentiometer with its terminals connected to the V_{out-} and V_{out2} pins and the wiper connected to the trim pin allows a variable trim, either up or down. This is shown in Figures 23, 24 and 25.

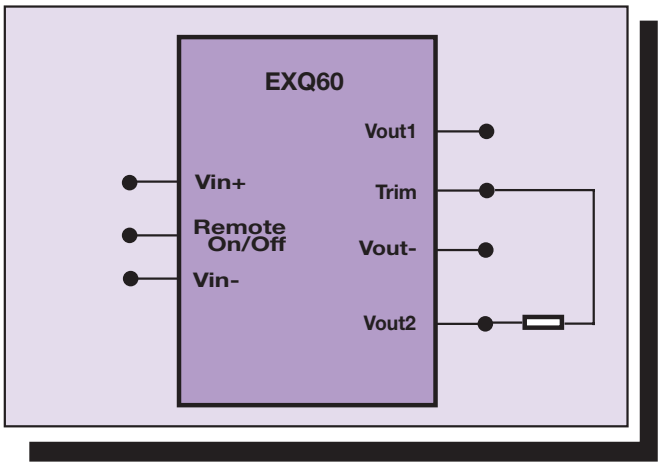


Figure 24 - Trimming Output Voltage - Trim Down

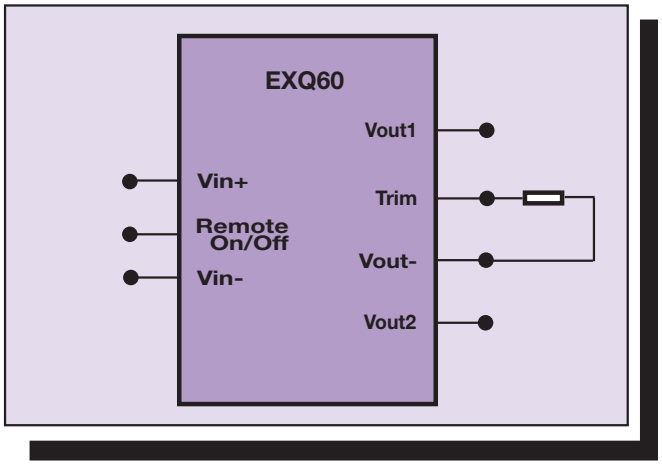


Figure 25 - Trimming Output Voltage - Trim Up

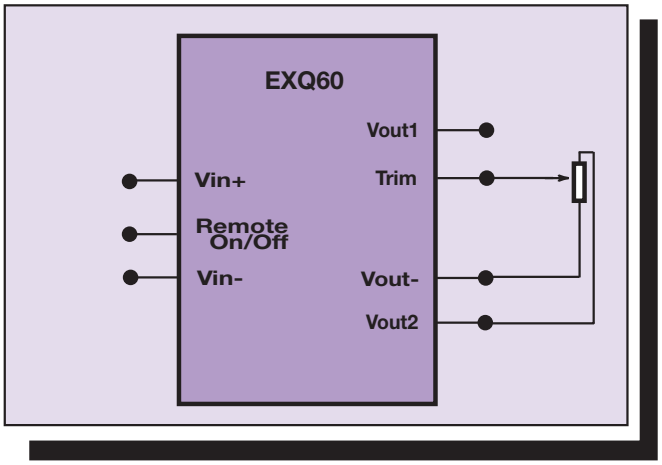


Figure 26 - Trimming Output Voltage - Variable Trim

The relevant trim curves to derive the appropriate trim resistance for the EXQ60 are shown in Figures 26, 27, 28 and 29.
The following equation can be used to calculate the resistor value (in Ω) needed to adjust the output voltage of either version of the EXQ60 either up or down. The only difference in the various calculations will be the co-efficients used in the equation. Δ% equals the percentage change required in the ouput voltages. Remember, both outputs of a converter will be adjusted up or down by the same percentage.

$$R_{trim} = (K1 / \Delta\%) - K2$$

Model	Trim-up		Trim-down	
	K1	K2	K1	K2
EXQ60-48D05-3V3	54,270	4,750	66,015	5,954
EXQ60-48D3V3-2V5	52,670	5,045	60,275	6,174

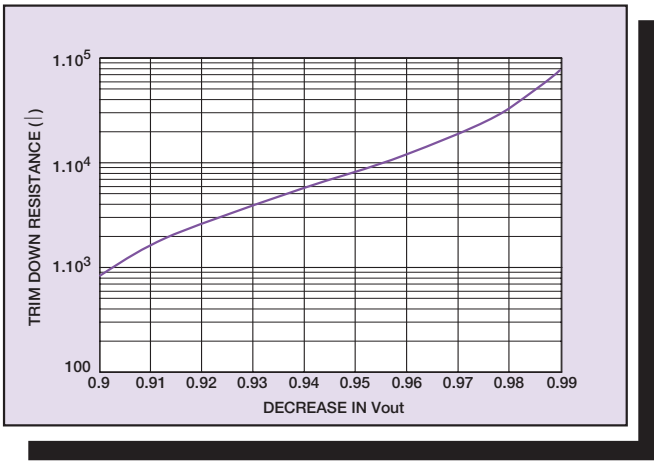


Figure 27 - EXQ60-48D05-3V3 Typical Trim-Down Curve (Resistor from TRIM to V_{o2}[1])

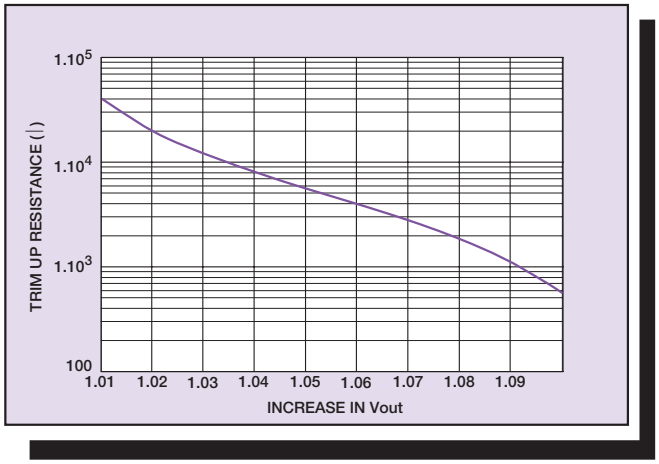


Figure 28 - EXQ60-48D05-3V3 Typical Trim-Up Curve (Resistor from TRIM to V_{o-})

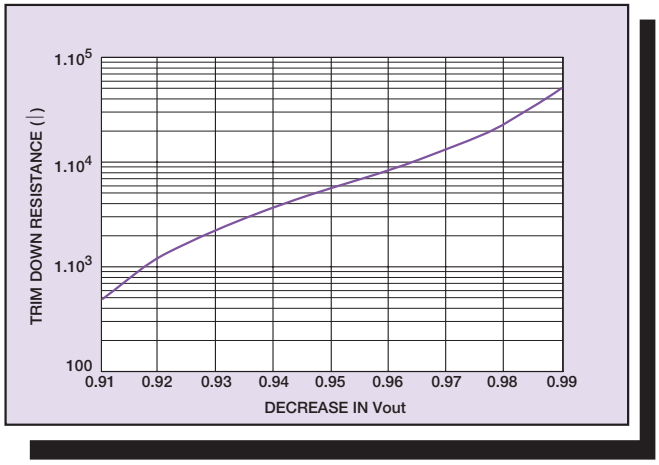


Figure 29 - EXQ60-48D3V3-2V5 Typical Trim-Down Curve (Resistor from TRIM to V_{o2})

The trim-down curve specifying resistance for a given decrease in nominal output voltage is the same for all models.

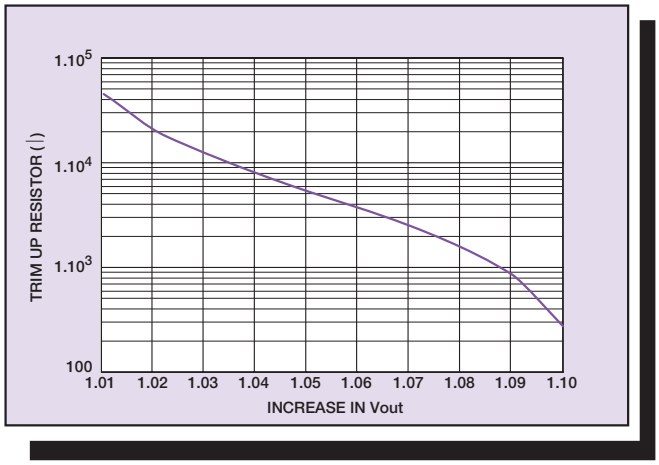


Figure 30 - EXQ60-48D3V3-2V5 Typical Trim-Up Curve (Resistor from TRIM to V_{o-})

When the output voltages are trimmed up a certain percentage, the output currents must be de-rated by the same amount so that the maximum output power is not exceeded.

8.6 Parallel and Series Operation

Because of the absence of an active current sharing feature, parallel operation of multiple EXQ60 converters is not allowed.

The individual outputs of the EXQ60 converters are not isolated and as such series operation is not allowed.

8.7 Output Capacitance

EXQ60 series DC/DC converters are designed for stable operation without the need for external capacitance at the output terminals. However, when powering loads with large dynamic current requirements, improved voltage regulation can be obtained through the use of such capacitance. The most effective technique is to locate low ESR ceramic capacitors as closely to the load as possible, using several capacitors to lower the overall ESR. These ceramic capacitors will handle the short duration high frequency components of the dynamic current requirement. In addition, higher value electrolytic capacitors should be used to handle the mid-frequency components.

Note that it is equally important to use good design practices when configuring the DC distribution system. As outlined in section 8.1, low resistance and low inductance PCB layout traces should be utilized, particularly in the high current output section. Generally, as a rule of thumb, 100µF/A of output current can be used without any additional analysis.

Note that the maximum rated value of output capacitance is specified in the long-form data sheet. If required, larger capacitance values are possible; please contact your local Artesyn Technologies representative for further information.

8.8 Reflected Ripple Current and Output Ripple and Noise Measurement

The measurement set-up outlined in Figure 30 has been used for both input reflected/capacitor ripple current and output voltage ripple and noise measurements on EXQ60 series converters. When measuring output ripple and noise, a 50Ω coaxial cable with a 50Ω termination should be used to prevent impedance mismatch reflections disturbing the noise readings at higher frequencies. The input ripple current measurement set-up is compatible with ETS 300 386-1.

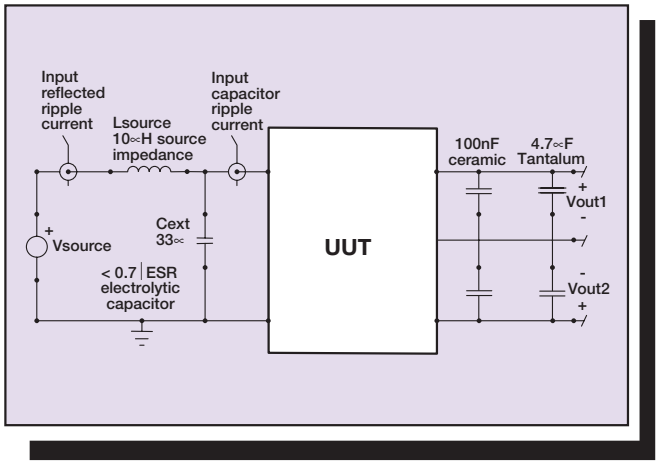


Figure 31 - Input Reflected Ripple/Capacitor Ripple Current and Output Voltage Ripple and Noise Measurement Set-Up

8.9 Compatability with ADM1070 Hot Swap Controller

Inserting circuit boards into a live -48V backplane can cause large input transient currents when large capacitances are charged. These transient currents can cause glitches on the system power supply and permanently damage components on the board. To ensure that the input voltage is stable and within tolerance before being applied to the DC-DC converter, Artesyn Technologies recommends the use of a hot-swap controller, such as the ADM1070 from Analog Devices. This device controls harmful transient currents and ensures safe insertion or removal of the application board from a live backplane.

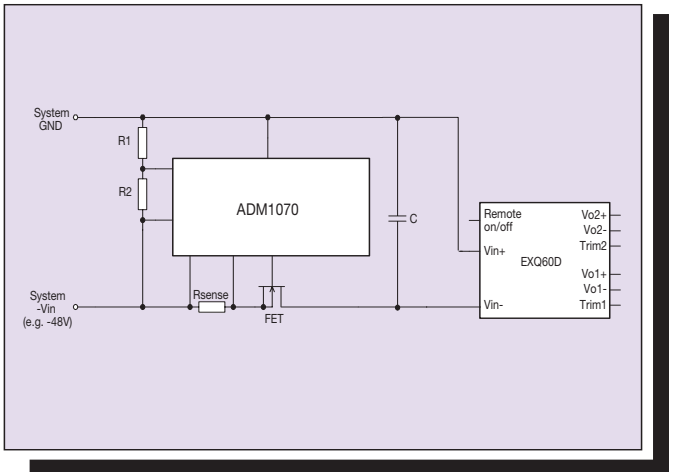


Figure 32 - Inrush Current Control using ADM1070

The ADM1070 is a 6-pin SOT-23, negative voltage hot-swap controller that allows a board to be safely inserted and removed from a live backplane. This product is compatible with the EXQ60 family. The ADM1070 provides the following features:

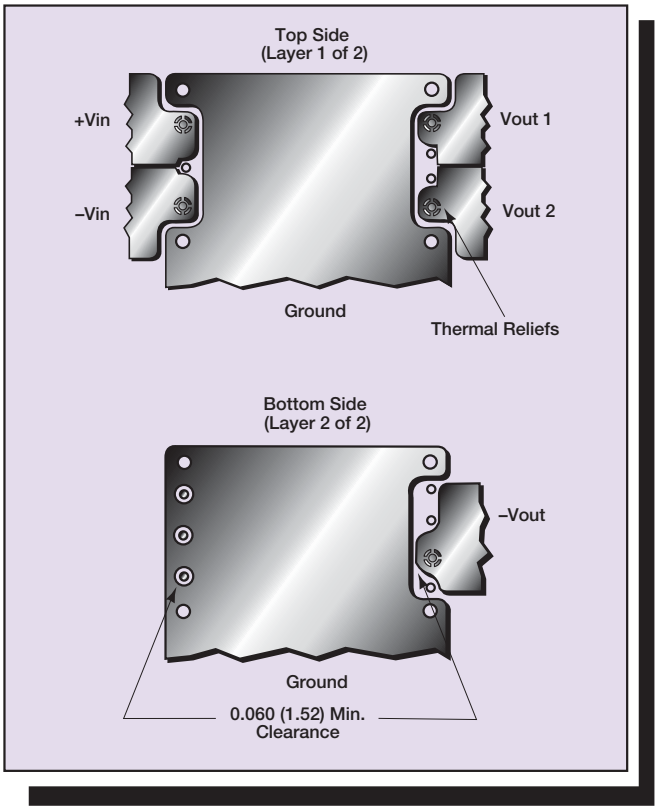
- Inrush current is limited to a programmable value by controlling the gate voltage of an external N-channel pass transistor
- The pass transistor is turned off if the input voltage is less than the programmable under-voltage threshold or greater than the over-voltage threshold. A programmable electronic circuit breaker protects the system against shorts.

The UV/OV pin can be used to detect under-voltage and over-voltage conditions at the power supply input. The EXQ60 already has in-built under-voltage protection to ensure that the unit does not draw power from the source for voltages less than approximately 30V. Users should refer to the data sheet of the ADM1070 for details on setting the required UVLO and OVLO trip levels.

The ADM1070 features a current limiting function that protects against short circuits or excessive supply currents. The flow of current through the load is monitored by measuring the voltage across the sense resistor, R_{sense}. The action taken by the controller in the event of an input over-current condition will depend upon the severity of that condition. Please refer to the ADM1070 product datasheet on www.analog.com for details.

9. Appendix 1 - Recommended PCB Footprints

VIEW IS FROM TOP SIDE



THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

ALL DIMENSIONS IN INCHES (mm)
ALL TOLERANCES ARE ±0.10 (0.004)

Figure 33 - Recommended Footprints